Techniques for MR Imaging Near Metallic Implants

Garry Gold, MD[1], Brian Hargreaves, PhD[1], Kim Butts Pauly, PhD[1], Nicholas Giori, MD[4], Scott Reeder, MD, PhD[3], Greig Scott, PhD[5], Ross Venook, MS[5], Nathaniel Matter, PhD[5], Sharon Ungersma, MS[5], Steve Conolly, PhD[2]

[1]Stanford University, Department of Radiology
[2]University of California Berkeley, Department of Bioengineering
[3]University of Wisconsin, Department of Radiology
[4]Stanford University, Department of Orthopedics
[5]Stanford University, Department of Electrical Engineering

Summary
Metallic implants, such as total joint replacements and spinal fixation devices, are increasingly common in an aging population. Failure or complications such as infection near these implants is frequent. Currently, there is no cross-sectional imaging technique that allows artifact-free imaging next to orhtopedic hardware. MRI would be the ideal way to evaluate tissue near these implants if effective strategies for reduction of atrifacts are developed. Several techniques, including VAT, IDEAL fat/water separation, and prepolarized MRI are promising methods to address this unmet need in clinical imaging.

Background: Magnetic resonance imaging is widely regarded as the best imaging modality for orthopedic conditions [1]. Unfortunately, in patients with previously implanted metallic hardware, MRI is extremely limited by artifacts. In these situations, there is currently no choice but to compromise, and base clinical decisions on poor quality MR images, CT (which also suffers from artifacts), or projection radiography. Due to the aging population and the rising number of total joint replacements done per year, revisions of total joint replacements due to failure have risen dramatically in the last 10 years with an incidence of approximately 70,000 per year [2]. The number of knee replacement surgeries tripled between 1990 and 2002 [2]. Van Gothem, et al. states *"In clinical practice, large metallic spinal fixation devices render MRI of the involved region of the spine virtually impossible"* [3].

Conventional MRI is limited near metal implants by susceptibility and RF shielding artifacts [4]. Detection of contrast enhancement and marrow edema with MRI, important in diagnosing infection, is also limited by poor fat saturation due to magnetic field inhomogeneity. Inversion recovery imaging gives consistent fat suppression, but at low signal-to-noise. There is currently a lack of effective fat suppression techniques that can be used with intravenous contrast near metal implants.

MRI Approaches: There have been several attempts to make MRI more effective near metal implants. View angle tilting (VAT) [5] eliminates in-plane distortions near metal implants [6, 7] and when used appropriately can be done without blurring [8]. However, slice profile distortions and out-of-slice artifacts are still problematic around metal implants [9]. Current work includes field map corrections for the slice profile distortions. Even with these corrections RF shielding near complex prostheses (such as total knee replacements) may still be limiting.

Newer approaches to fat suppression include Iterative Decomposition of water and fat with Echo Asymmetry and Least-Squares Estimation (IDEAL) imaging [10]. This technique allows acquisition of water and fat images in the presence of inhomogeneity caused by metal, and the acquisition of T1-weighted images after gadolinium with fat/water separation (Figure 1). IDEAL requires 3 acquisitions, but the increase in scan time can be offset by protocol modification or the use of parallel imaging.

Prepolarized MRI replaces the expensive superconducting main field magnet of a conventional MR scanner with two inexpensive electromagnets [11]. This replaces the single static magnetic field with two dynamic magnetic fields: a *polarizing* field and a *readout* field. The polarizing field creates the sample magnetization while the readout field determines the acquisition frequency. Because of the low-field readout, B0 susceptibility artifacts are virtually eliminated. This is quite helpful for imaging patients with metal implants.

Conclusion: Effective imaging near metallic implants with MRI is certainly an unmet need, but there are several MR software and hardware developments that promise to address this important area.
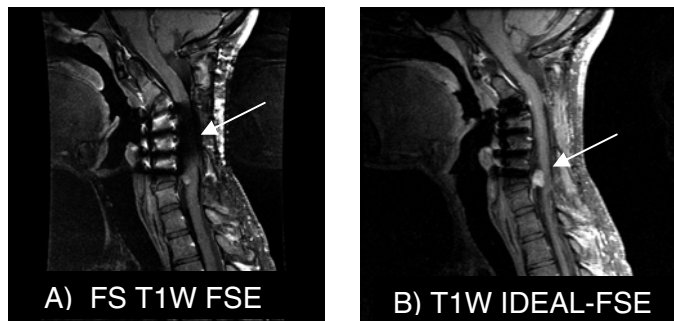

A) FS T1W FSE

B) T1W IDEAL-FSE

Figure 1: A) Fat suppressed, post contrast T1-weighted fast spin echo (FSE) image from the cervical spine in a patient with a metal plate and screws. The cervical spinal cord (arrow) is obscured. B) T1-weighted IDEAL-FSE image from the same location. The cervical spinal cord is well seen and an enhancing neurofibroma next to the cord is identified (arrow).

References

1. Resnick D. *Diagnosis of Bone and Joint Disorders*. New York: Saunders, **2002**
2. Kurtz S, Mowat F, Ong K, Chan N, Lau E, Halpern M. Prevalence of primary and revision total hip and knee arthroplasty in the United States from 1990 through 2002. *J Bone Joint Surg Am* **2005**;87:1487-1497
3. Van Goethem JW, Parizel PM, Jinkins JR. Review article: MRI of the postoperative lumbar spine. *Neuroradiology* **2002**;44:723-739
4. White LM, Buckwalter KA. Technical considerations: CT and MR imaging in the postoperative orthopedic patient. *Semin Musculoskelet Radiol* **2002**;6:5-17
5. Cho ZH, Kim DJ, Kim YK. Total inhomogeneity correction including chemical shifts and susceptibility by view angle tilting. *Medical Physics* **1988**;15:7-11
6. Kolind SH, MacKay AL, Munk PL, Xiang QS. Quantitative evaluation of metal artifact reduction techniques. *J Magn Reson Imaging* **2004**;20:487-495
7. Olsen RV, Munk PL, Lee MJ, et al. Metal artifact reduction sequence: early clinical applications. *Radiographics* **2000**;20:699-712
8. Butts K, Pauly JM, Gold GE. Reduction of blurring in view angle tilting MRI. *Magn Reson Med* **2005**;53:418-424
9. Butts K, Gold GE. Correction of Slice Profile Distortion from Metallic Devices. In: *ISMRM*, **2006**
10. Reeder SB, Pineda AR, Wen Z, et al. Iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL): application with fast spin-echo imaging. *Magn Reson Med* **2005**;54:636-644
11. Morgan P, Conolly S, Scott G, Macovski A. A readout magnet for prepolarized MRI. *Magn Reson Med* **1996**;36:527-536